Scaling-up and characterization of ultralow-loading MEAs fabricated by electrospray

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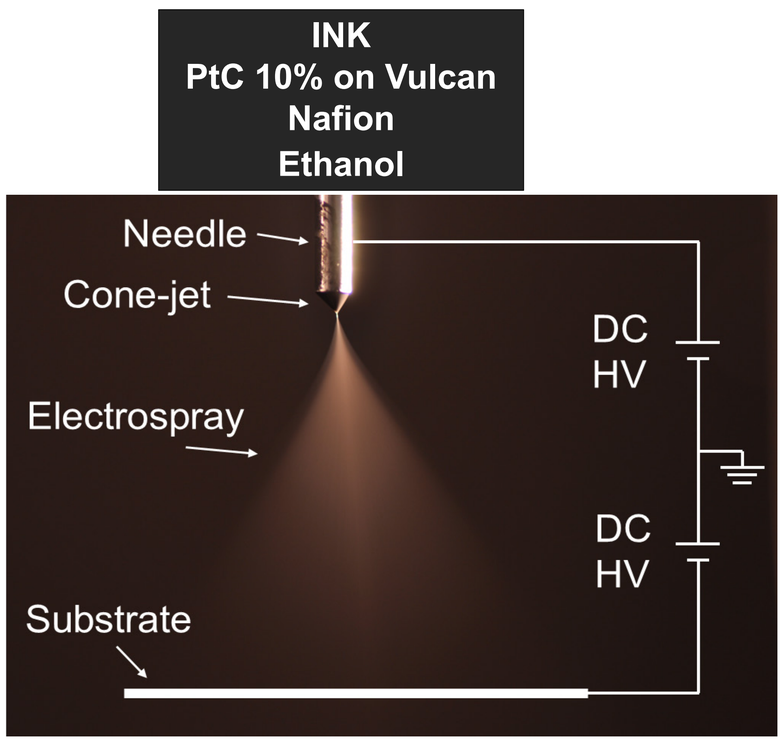
Introduction

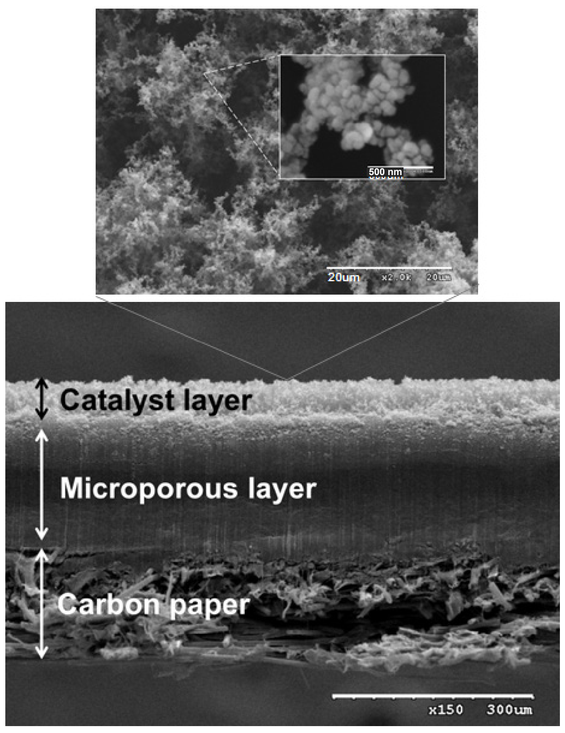
- The electrospray aerosol technique is used to generate nano-structured catalytic layers by random aggregation of Pt/C nanoparticles.
- Ultralow-loading PEMFC MEAs with 0.02 mg_{Pt}/cm^2 (global loading) were produced by using this technique.

Experimental

- Catalyst layers with 25 cm^2 active area and 0.01 mg_{Pt}/cm^2 ultra-low Pt loadings were deposited by catalyst electrospraying on the MPL of the electrodes.
- Membrane-electrode assemblies (MEA) were prepared with Nafion® membrane sheets sandwiched between two equal electrodes.

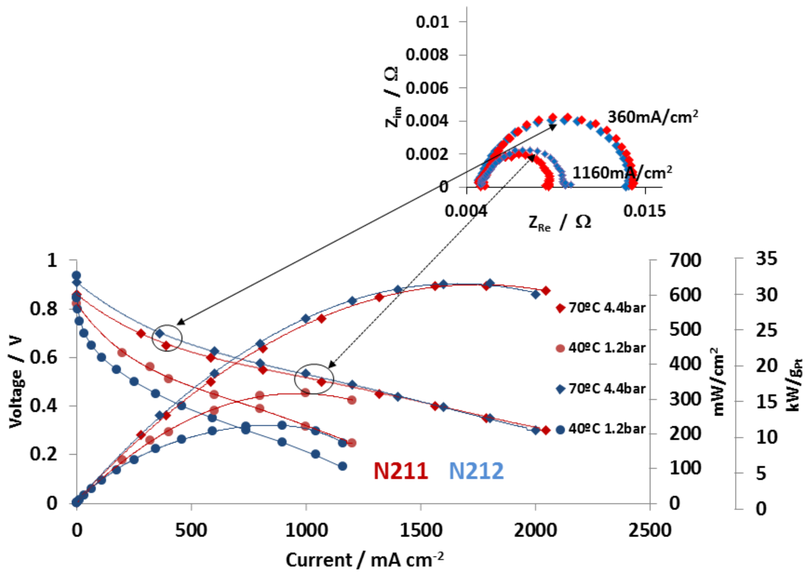


Electrospraying of a catalytic ink. The nanostructured material grows over the microporous layer (substrate)



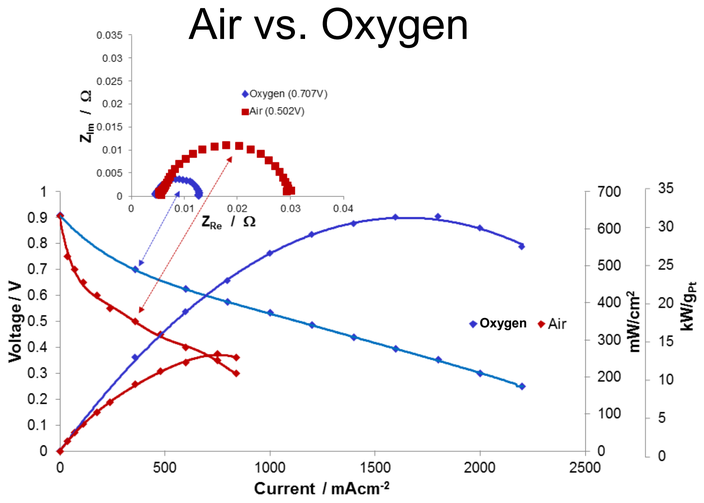
SEM images of electrodes with 0.01mgPt/cm^2 load obtained by the electrospray method. Fractal morphology is shown in the upper view of the catalytic deposit.

Nafion® 212 vs. Nafion® 211



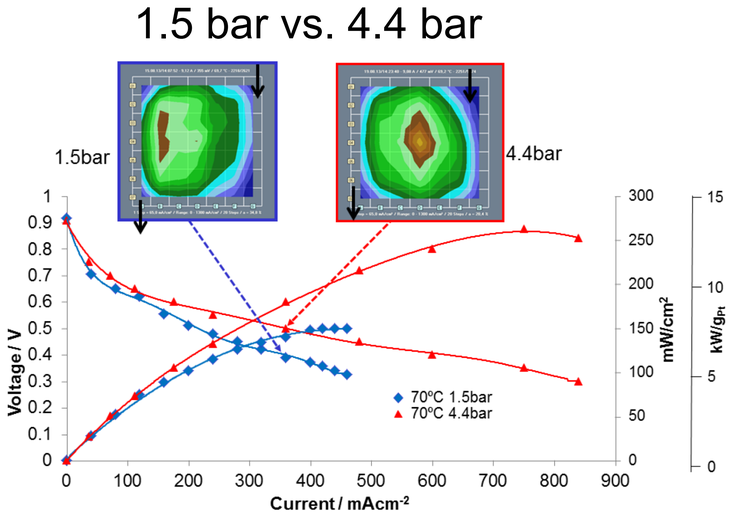
Comparison of the current–voltage characteristics and power density curves obtained with MEAs with the same Pt loading of 0.01mg_{Pt}/cm^2 and different Nafion® membranes (N212 vs. N211). Electrochemical impedance spectroscopies were obtained for constant current. Operating conditions were 70ºC / 4.4bar and 40ºC / 1.2bar. Feeding with dry H_2 and O_2 (λ_{O_2}=2.5 λ_{H_2}=1.5).

Air vs. Oxygen



Comparison of the current–voltage characteristics and power density curves obtained with MEAs with the same global Pt loading of 0.02 mg_{Pt}/cm^2, N212 and different cathode feeding gas (oxygen vs. air). Electrochemical impedance spectroscopy is compared for 360 mA/cm^2. Operating conditions were: 70 ºC - 4.4 bar, relative humidity 15%, feeding gases: H_2/O_2 (λ_{O_2}=2.5 λ_{H_2}=1.5) vs. H_2/air (λ_{air}=2.0 λ_{H_2}=1.5).

1.5 bar vs. 4.4 bar

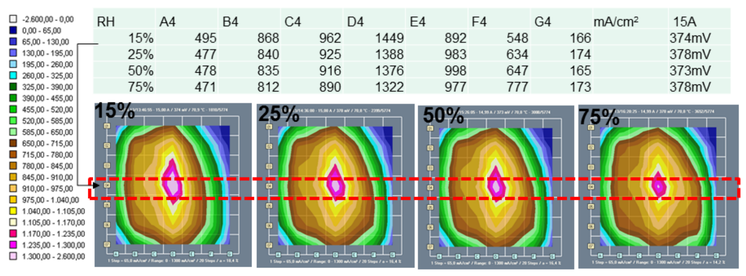


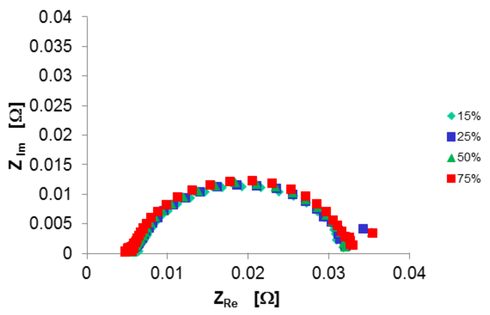
Comparison of the current–voltage characteristics and power density curves obtained with MEAs with the same global Pt loading of 0.02 mg_{Pt}/cm^2, N212 and different pressures. Segmented cell results of local current density (average value 360 mA/cm^2, see scale on next figure). Operating conditions were: 70 ºC / 4.4bar and 70 ºC / 1.5 bar. Feeding with H_2 and air (λ_{air}=2.0 λ_{H_2}=1.5), relative humidity RH = 25%.

Summary of results

- O_2-H_2 dry feeding gases (self-humidification):
  - Maximum performance at T = 70 ºC, P = 4.4 bar:
    - ✓Power density: 600 mW/cm^2
    - ✓Platinum utilization: 30 kW/g_{Pt}
  - Maximum performance at T = 40 ºC, P = 1.2 bar:
    - ✓Power density: 200 mW/cm^2 (Nafion 212)
    - ✓Platinum utilization: 10 kW/g_{Pt} (Nafion 212)
  - No significant improvements by external humidification
- Air-H_2 humidified feeding gases:
  - Maximum performance at T = 70 ºC, P = 4.4 bar, RH = 25%:
    - ✓Power density: 250 mW/cm^2
    - ✓Platinum utilization: 12.5 kW/g_{Pt}
  - Maximum performance at T = 70 ºC, P = 1.5 bar:
    - ✓Power density: 150 mW/cm^2 (Nafion 212)
    - ✓Platinum utilization: 7.5 kW/g_{Pt} (Nafion 212)
  - No significant changes by varying the humidification above a threshold value (~15 %).

Relative Humidity





Relative humidity study for 600 mA/cm^2. Operating conditions were: 70 ºC / 4.4 bar and feeding gases H_2/air (λ_{air}=2.0 λ_{H_2}=1.5). MEAs with 0.02 mg_{Pt}/cm^2 global Pt loading and N212. Segmented cell results (left) and electrical impedance spectroscopy (right) exhibit similar performance under humidity variation above RH = 15 %.

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